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Determination of the phase–centre of a u.h.f. ruggedised log–periodic aerial in the H–plane

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DETERMINATION OF THE PHASE-CENTRE OF A UHF RUGGEDISED LOG-PERIODIC AERIAL IN THE H-PLANE

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Summary

The phase-centre concept as applied to a log-periodic aerial is discussed. The radiation pattern phase of a u.h.f. ruggedised log-periodic aerial is used to establish its 'apparent' phase-centre in the H-plane.

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DETERMINATION OF THE PHASE-CENTRE OF A UHF RUGGEDISED LOG-PERIODIC AERIAL IN THE H-PLANE

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1. Introduction

A u.h.f. ruggedised log-periodic aerial was described in a previous report.[1] A subsequent report[2] considered an array of four log-periodic aerials suitable for re-broadcast link reception at certain relay stations. A reference was made there to the term 'phase-centre' when applied to a log-periodic aerial. This report sets out to amplify that statement and to establish the phase-centre position of a dielectric-loaded log-periodic aerial in the H-plane by measurement.

2. Phase-centre concept

When calculating the radiation pattern of an array of aerials it is necessary to associate with each individual aerial a specific reference point from which radiation may be said to emanate. This point can be considered as the phase-centre of the radiated field from an aerial.

Consider the general expression for the far field of an aerial at a point, P

$$e(P) = \frac{1}{r} E(\theta, \phi, f)\exp\left\{-jk[r - F(\theta, \phi, f)]\right\} \quad (1)$$

where E is the amplitude of the field

- k is the phase constant, $\frac{2\pi}{\lambda}$
- λ is the wavelength
- f is the frequency of operation
- r, θ, ϕ are the variables of a spherical co-ordinate system defining P.

The phase-centre of an aerial is, if it exists, that origin of the co-ordinate system (r, θ, ϕ) which makes the phase function, $F(\theta, \phi, f)$ independent of θ and ϕ. For most aerials it is not possible to define such a point. However, in some cases, it may be possible to identify an 'apparent' phase-centre if the phase remains tolerably constant when either of the angular variables associated with the phase function are restricted in range.[3]

Because of the tapered spacing of dipole elements and the complex amplitude and phase distribution in the radiation field, the log-periodic aerial does not have a unique phase-centre. An 'apparent' phase-centre which is frequency dependent can be found for vertical or horizontal polarisation separately provided the angular range of inclination or azimuth is restricted to the main beam region. Outside the main beam region the radiation pattern amplitude is very low and the fact that a phase-centre cannot be found there may not be very significant in practical applications. Only the 'apparent' phase-centre of the log-periodic aerial in the H-plane is dealt with in this report.

3. Determination of phase-centre

A phase-centre for a particular aerial can be found theoretically only if the phase function is known explicitly. For the log-periodic aerial the most satisfactory method of finding the 'apparent' phase-centre is by experiment. If no means of rotating the test aerial are available the phase-centre can be deduced from the amplitude radiation pattern measured along a number of radials.[3] In this method the distances between the aerial and measuring point have to be very accurately measured.

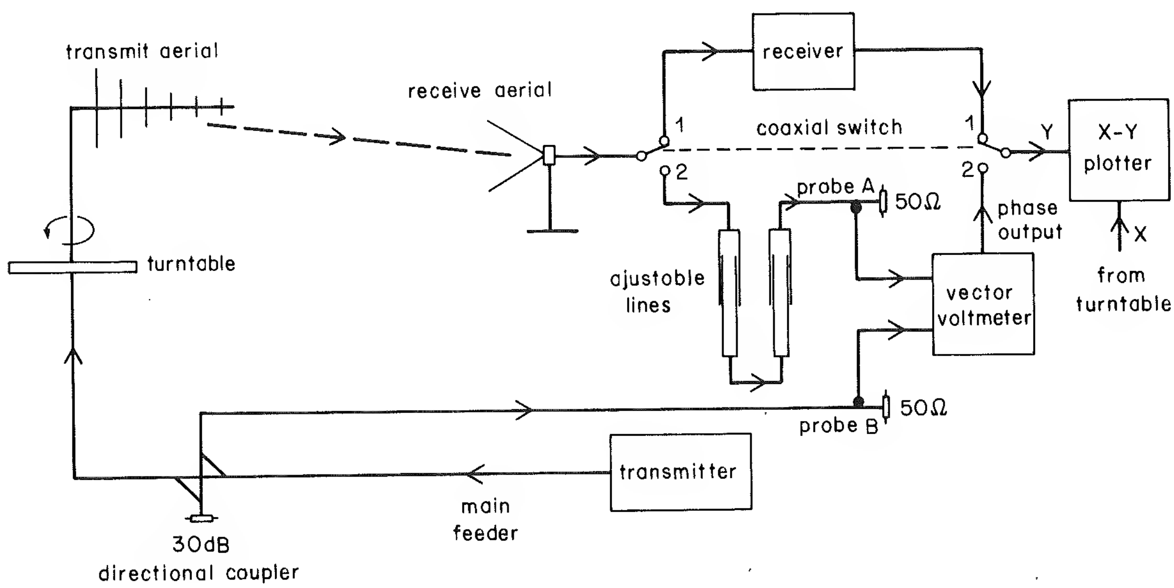

Fig. 1 - Measurement of complex radiation pattern

The most straight-forward approach is to measure the phase pattern of the aerial. Two methods of deriving the phase-centre from these measurements are described in detail in the following sections.

3.1. Measurement of radiation pattern phase

The test aerial is rotated in the desired plane of polarisation. The radiation pattern phase is found by comparing the phase of the transmitted signal from the test aerial with that of a reference signal derived from the feed to that aerial. A vector voltmeter is used for this purpose. Some degree of automation is achieved by linking the phase output from the vector voltmeter and a voltage proportional to the angle through which the aerial is rotated to an X-Y plotter. The arrangement is shown in Fig. 1.

A co-axial switch is used to change between amplitude pattern measurement (1) and phase pattern measurement (2). It is convenient to observe the amplitude of the received signal initially for setting up purposes. For phase measurement it is necessary to avoid a large difference, i.e. many wavelengths, between the electrical path length from the transmitter to the two vector-voltmeter probes. Failure to do this renders the measurement accuracy sensitive to the frequency stability of the signal source. The 30 dB

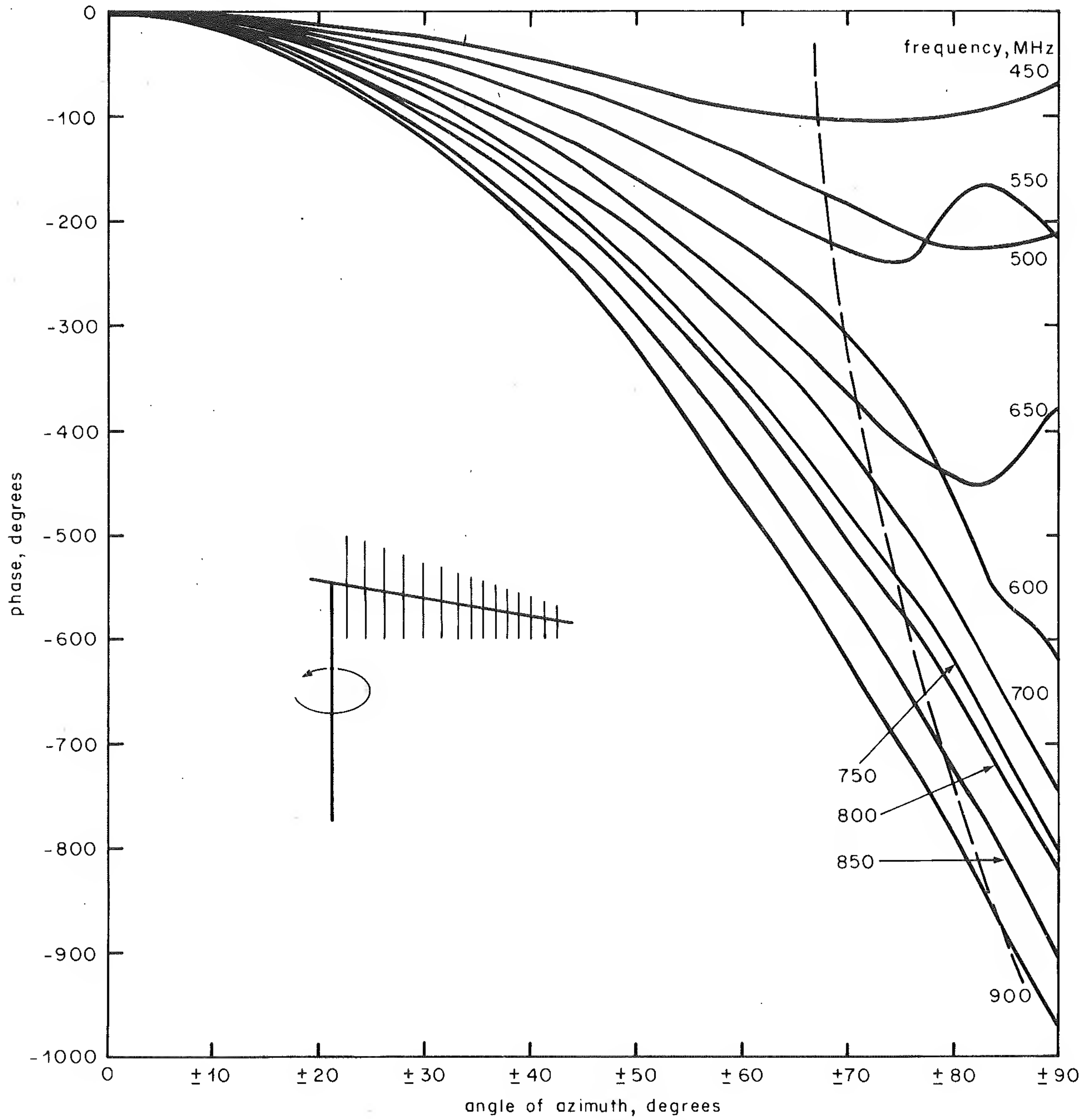

Fig. 2 - Radiation pattern phase of ruggedised log-periodic aerial in the H-plane

Reference point taken as front of short-circuit plate

— — — locus of angles where amplitude of radiation pattern is −20 dB relative to maximum field

directional coupler ensures that the signals at the vector-voltmeter probes are of the same order of magnitude.

The aerial under test is rotated in the H-plane about a point along the axis of the aerial at the front of the short circuit plate.[1] The adjustable lines are used to set the relative phase to zero when the aerial is directed towards the receive aerial. The results of the measurements taken over angles of azimuth -90° to $+90^{\circ}$ are summarised in Fig. 2. The locus of angles where the amplitude of the radiation pattern is -20 dB relative to maximum field is also indicated. Within the region bounded by this curve, which can be taken to be the 'main-beam' region, the phase variation appears to be well behaved.

3.2. Fixed point of aerial rotation: Method 1

The radiation pattern phase measurements enable the phase-centre to be calculated directly. The symmetry

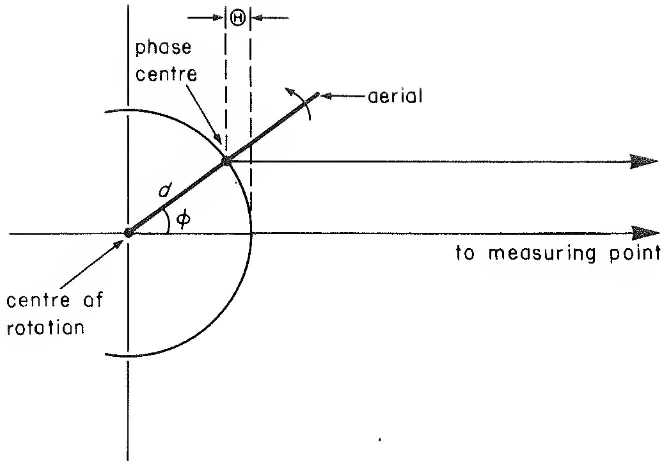

Fig. 3 - Rotation of aerial about a fixed point; geometry and phase change

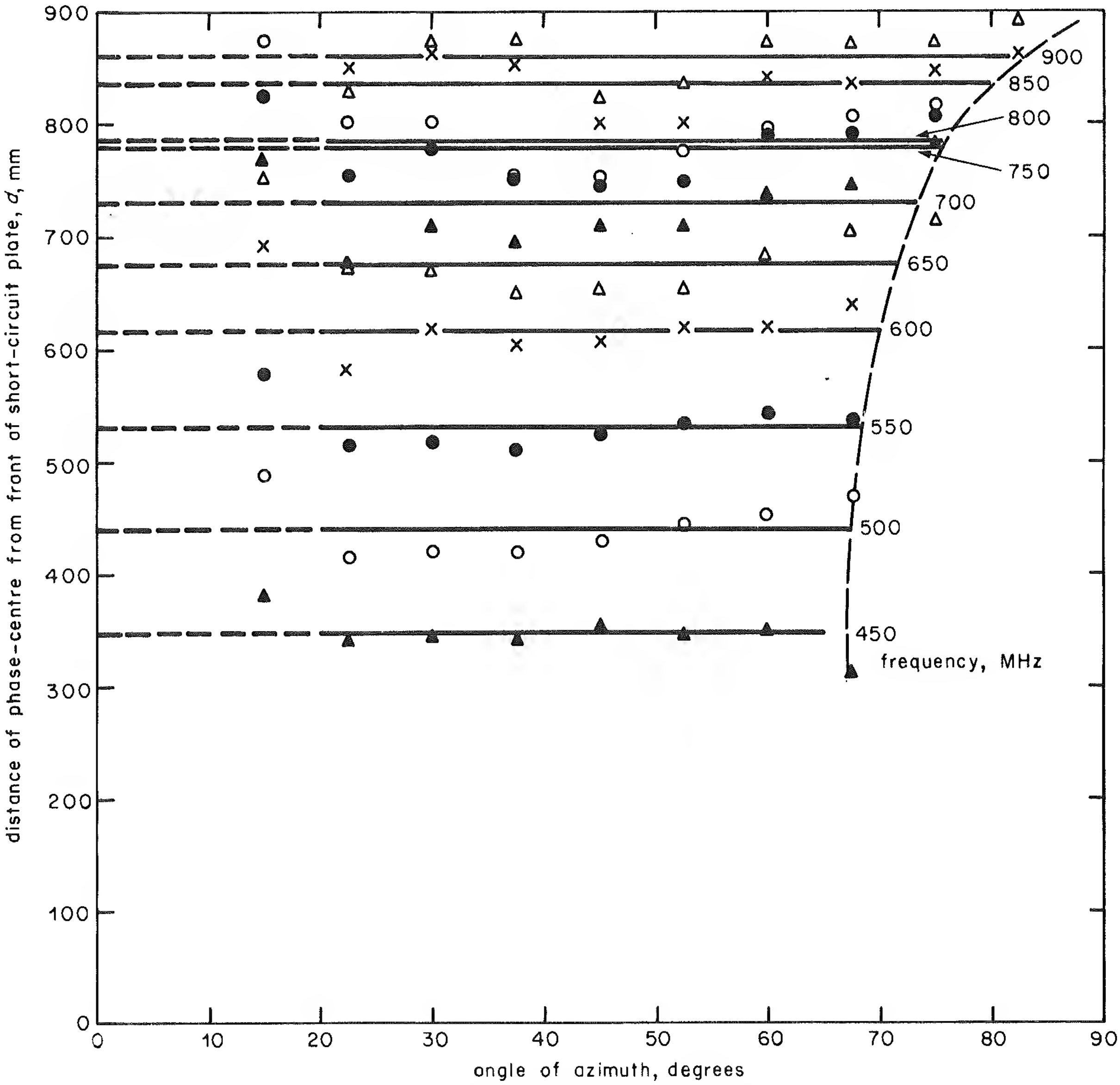

Fig. 4 - Location of phase-centre position: Method 1

— — — locus of angles where amplitude of radiation pattern is -20 dB relative to maximum field

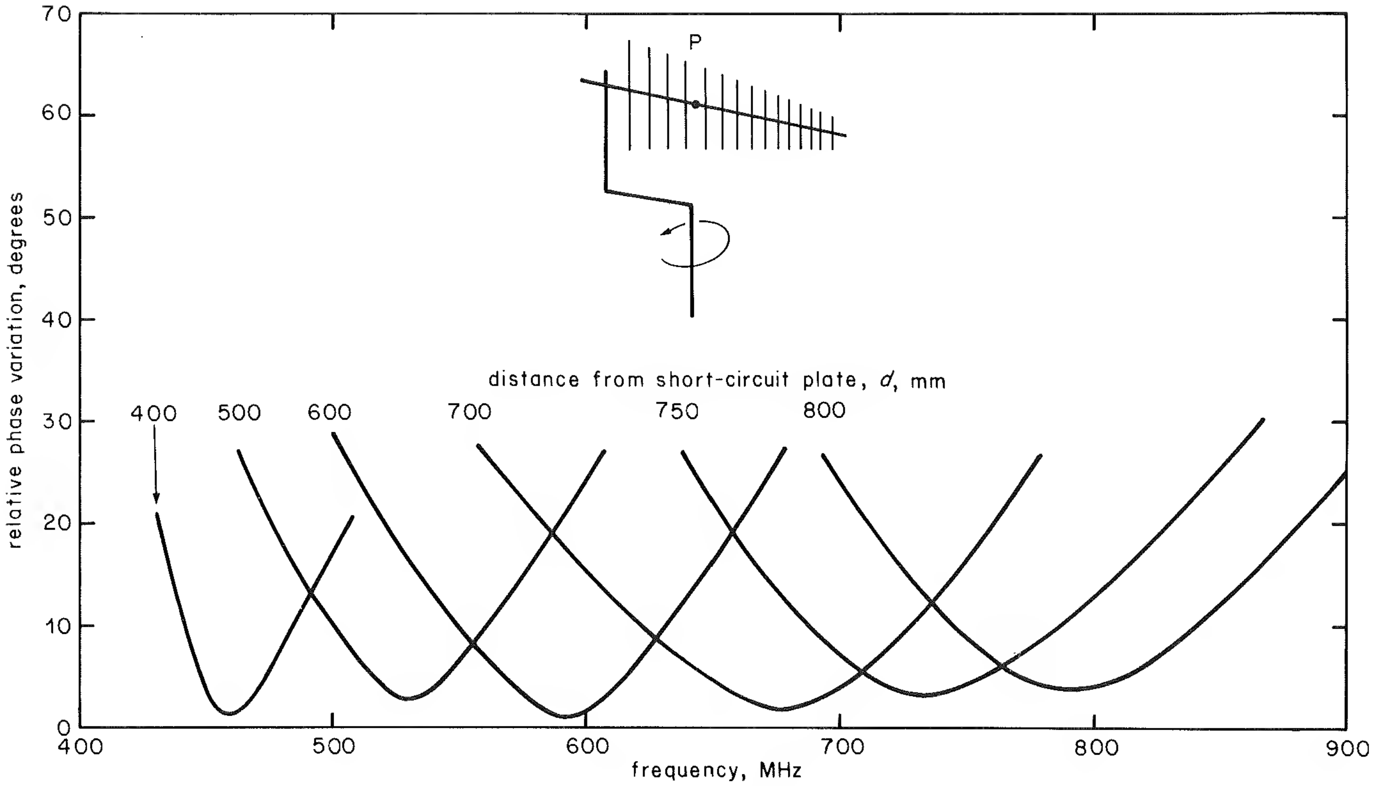

Fig. 5 - Location of phase-centre position: Method 2

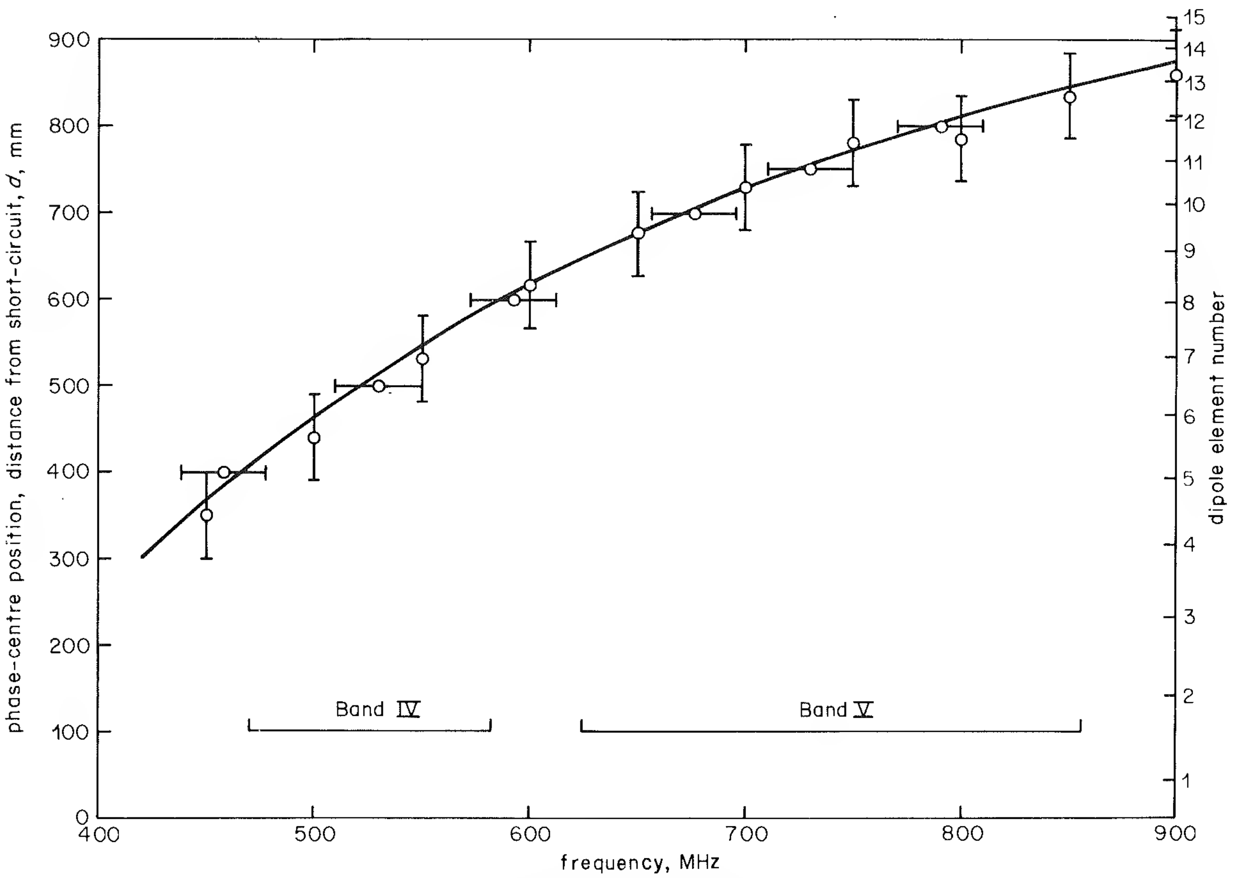

Fig. 6 - Phase-centre position of ruggedised log-periodic aerial in the H-plane

Method 1 — Method 2 — Measured phase-centre position

of the phase response about 0° azimuth indicates that the phase-centre lies on the aerial axis. Consider the phase change which takes place when the aerial is rotated through an angle ϕ. Referring to Fig. 3 the phase change, Θ, is given by

$$\Theta = \frac{2\pi}{\lambda} d(1 - \cos \phi) \qquad (2)$$

where d is the distance of the phase-centre from the centre of the rotation.

Re-arranging (2), we have

$$d = \frac{\lambda}{2\pi} \frac{\Theta}{(1 - \cos \phi)} \qquad (3)$$

The results of calculating d for several angles of azimuth and several frequencies are shown in Fig. 4. The phase-centre position remains reasonably constant at each frequency over the main-beam region, and the averaged values may be taken as the 'apparent' phase-centre of the aerial.

3.3. Variable point of aerial rotation: Method 2

By moving the point of rotation of the aerial along its axis and repeating the radiation pattern phase measurements the phase-centres at different frequencies may be found by observing the minima in the phase response. The results are presented in a condensed form in Fig. 5. The minimum detectable phase change is limited by the sensitivity of the measuring apparatus, which appears to be better than $\pm 4^\circ$.

3.4. Assessment of results

The results of both methods of determining the phase-centre position are given in Fig. 6. The scale at the right hand side of the figure indicates the positions of the aerial dipole elements. The tolerances indicated cover the inaccuracies involved in maintaining and measuring the aerial position and the method of measuring the radiation pattern phase.

The phase-centre is found to lie on a locus of $1{\cdot}54\lambda$ from the virtual apex of the aerial which is taken to be 1·39 m from the front of the short-circuit plate. This result is dependent upon the aerial parameters which are for reference τ = 0·93, σ = 0·18, 15 elements. The results agree with those of Carrel[4] in his original paper on log-periodic aerials.

4. Conclusions

An 'apparent' phase-centre can be defined for the u.h.f. ruggedised log-periodic aerial in the H-plane over a limited azimuthal range. The phase-centre is found to be $1{\cdot}54\lambda$ from the virtual apex and is assumed to lie on the aerial axis.

5. References

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